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ENGINEERING AND DEVELOPMENT PROGRAM PLAN-NAVIGATION

FEDERAL AVIATION ADMINISTRATION

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ENGINEERING AND DEVELOPMENT

PROGRAM PLAN

NAVIGATION

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DEPARTMENT OF TRANSPORTATION
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16. Abstract

This program development plan provides the frame work for the development of CONUS and Oceanic Navigation Systems necessary for projected traffic loads into the 1980's. Program goals, approach, development activities, and expected results are set forth.

The program is based on the continuing role of VORTAC as the primary means of navigation in the airways system into the 1980's. Concurrently programs have been established to determine the feasibility for adoption of VLF systems, such as Omega, for aviation users in both oceanic and continental applications.

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NAVIGATION PROGRAM (040)

EXECUTIVE SUMMARY

This plan includes the engineering and development Program Elements which have been established to meet current and future navigation demands for the enroute, terminal, and oceanic environments. The basic mission is to increase capacity and reduce system costs while maintaining, as a minimum, present safety standards.

- VORTAC Systems (041/042)

  Since this system will continue to be the primary system for the great majority of users well into the future, a number of major efforts are included to improve the system from an operational standpoint. These projects will hopefully improve the signal quality by minimizing siting and weather effects and reduce maintenance costs through the development of highly reliable solid state retrofit components as well as maintenance sensors which would allow the application of more efficient maintenance concepts.

  This plan also recognizes the fact that route width reduction and RNAV 3D/4D applications in high density areas, especially near terminals, may also require major improvements in NAVAID accuracies. Therefore, due to the lengthy development/implementation cycle usually required for major NAVAID changes, projects have been initiated to develop feasibility models of precision VORs which would safely allow separation standard reduction. A multiple DME approach is an alternative to achieving the necessary accuracies required to reduce separation standards.

- VLF/Oceanic Navigation Systems (043)

  Recent commercial development of navigation receivers utilizing VLF signals emanating from the still incomplete Omega Network and existing Naval Communications Stations has caused a consid able interest within the FAA and the aviation community. Its application as a supplement to the VORTAC system is attractive for supplying a navigation capability to those areas without sufficient VORTACs such as Alaska, off shore or in extremely difficult siting areas (e.g. the valleys in the Rocky Mountain Region). The use of these devices as error bounding aids is also being investigated to allow improvement in oceanic capacities.

  The role of satellites for civil navigation purposes is not yet established. Therefore, the present program is only attempting to keep abreast of current efforts by other segments of the government. Projects relating to self-contained systems are

also minimal and are limited to studying methods for periodic update and error bounding to economically reduce oceanic separation standards and provide a practical replacement for Loran A.

- Area Navigation (RNAV) System Design (044)

  This effort is the validation of the concepts and principles and techniques which will allow the efficient and smooth application of area navigation (RNAV) to the total NAS environment. This includes the efforts to simulate the effects of this concept on the ATC System, insure a system design which will allow practical use by the large segment of the aviation community, and to measure the extent that this technique will increase system capacity and utility. It is planned that the application of these techniques will not only increase system flexibility but also eventually reduce the required number of NAVAIDs with a corresponding decrease in system maintenance and capital investment, allowing an orderly transition to the Advanced Air Traffic Management System (AATMS).

- QSAT System Support (045)

  The unique requirements of short haul aircraft are supported in this program element. Avionic developments in the RNAV area and NAVAID developments in the VORTAC and VLF areas will be applied to this particular application.

- Frequency Spectrum Planning (046)

  This element is intended to minimize the frequency spatial/spectral problem. The affect of channel splitting on currently used receivers will be measured and techniques to allocate new frequencies will be developed and validated.

- Navigation Systems (047)

  This program recognizes the fact that the capacity problems will undoubtedly be solved by a combination of improvements not only within the navigation discipline but also between the ATC Automation Program and the Navigation Program. For this reason, a system program element is included to establish trade-offs between elements within and without the Navigation Program.

  The Department of Transportation's National Plan for Navigation dated April 1972, is the overall plan which considers the current and future needs of civil air and marine interests of the United States. It also considers the interface with military users. The Area Navigation Program Plan (FAA-ED-04-2) details its own specific effort.

1.0 GENERAL DISCUSSION

Present navigation systems are generally classified into two major groups; (1) ground based short-distance aids which include VORTACs and (2) self-contained oceanic systems which include inertial (INS) and Doppler systems. This latter group is supplemented by ground based aids such as LORAN A and CONSOLAN. These major systems have proven adequate in the past, and efforts to sustain and improve these equipments will continue. The supplementary systems are gradually being phased out and must eventually be replaced. The LORAN C, Omega and a hyperbolic system based on signals from VLF Communication Station Systems are prime contenders for this function.

This Navigation Program is based on the continuing role of VORTAC as the primary means of navigation within the airways system into the 1980's. Major efforts are directed toward improving the quality of the existing system, reducing the continuing maintenance overhead, and developing new capabilities to meet future capacity requirements. The study, analysis and development of supplementary navigation systems which include VLF, self-contained, and satellites are or will be initiated.

The advent of higher traffic densities and new operational requirements has created doubts about the capability of the present VORTAC system to provide tolerable service in the future. When a change will be necessary is not exactly known, but it could occur before 1980. In order to be prepared for this eventuality, two major efforts have been initiated: improvements to the VORTAC System to allow a more accurate and reliable signal, and the development of an area navigation (RNAV) capability which would allow more efficient use of the available airspace than the present radial system. The latter technique could temper the need for reduced separation standards in all but the most congested high-density area. New landing aids such as the Microwave Landing System (MLS), designed to alleviate terminal area capacity problems, may require VORTAC accuracy improvements in the transition area to be fully effective. Also, adequate coverage in high density areas due to siting factors is still a nagging problem. This is especially critical where the extension of the service volume to satisfy new user airspace requirements for the Quiet Short-haul Air Transportation System (QSATS) is an added requirement.

RNAV places an additional burden on the present system since a large majority of the VORTAC radials will be utilized for definition of routes as opposed to a few specific radials now required for the current airways. This will require additional efforts to minimize signal distortion caused by siting problems in high density areas.

More stringent accuracies and the necessity of fewer siting effects are also predicted for more sophisticated navigation systems which will use the VORTAC signal to computer complex flight paths that include the vertical (3D) and time (4D) dimensions. In addition, rapidly expanding aviation services have caused acute frequency congestion in certain areas of the country. Therefore, the agency is presently in the process of doubling the available channels in the VOR and TACAN (DME) frequency bands by decreasing the facility channel spacing. The additional channels will be used for new ILS and VORTAC facilities. The corresponding modifications to the airborne equipments, (in some cases replacement will be necessary) will further increase the total system capital investment. The end result will be a further pressure to extend the system life. This and other factors have led to ICAO agreements which will extend the life . the VORTAC system until 1985, at the earliest.

The intensity and timing of the demand factors, the availability of the new systems, the time required for transition between the existing and new systems, and the capital investment factors are important tradeoffs which will influence the life of the VORTAC system as the primary navigation system. Therefore, the modification of the VORTAC system to fully achieve its inherent accuracy will be carefully considered.

From an oceanic and Advanced Air Transportation System (AATMS) standpoint, several other navigation systems which include VLF ground systems and satellites are also under consideration. These systems all have better low altitude coverage for continental applications and may eventually be less costly to maintain due to the reduced number of required reference stations. The accuracy reliability, availability and the practicality of low cost avionics for these systems must still be validated.

There is a growing interest within the FAA and the aviation community in meeting the navigation requirements that cannot be met by the VOR/DME navigation system. These requirements include: (1) provision of both IFR and VFR navigation service to those aircraft operations in remote areas that are not currently serviced by VOR/DME, (2) provision of a navigation service which cannot be met by VOR/DME due to line of sight limitations and mountainous terrain (e.g., Rocky Mountain area). The reality and extent of user requirements as described in these three items must be determined; the responsibility of the FAA to provide a navigation service which specifies the requirements must be evaluated. Previous work by the FAA has reduced the possible techniques to one that appears to be practical, and that is VLF navigation. In this context "VLF navigation" includes the Omega system and VLF communication signals. A more detailed approach to evaluation of Omega and VLF communication signal navigation

is given in the "VLF and Oceanic Navigation Program Element" section of this document. In addition to the technical efforts, a survey of user requirements for navigation has been initiated and will continue until a reasonably valid picture is assembled.

It is intended that the Navigation Plan be flexible so that the development efforts in any of the three major areas (VORTAC, RNAV, VLF) be time phased to provide the optimal system for all users as demand factors dictate. At the same time, the plan is interrelated so that the status of competing systems can be compared to each other and the demand factors as an aid in describing the overall program. The time-phasing and major milestones are depicted on Figure 1. (Navigation - Master Program Chart)

At present funding levels, the feasibility of these techniques will be determined by 1976 to allow implementation before 1980, if necessary. Obviously, new systems must be developed well before the present system becomes obsolete. The new system should not be developed on a "crash" basis necessitating a disproportionate and inefficient expenditure of resources in a short time period. On the other hand, extended development efforts to improve the present system cannot be ignored, because there is the possibility that new systems will not be developed in time. Therefore, some developments presently initiated are to some degree simply insurance against possible uncontrollable variations of the demand/development factors. For example, if traffic loading increases before the adequate development of the Wide Aperture VOR, the FM/FM PVOR could be implemented as an interim measure. On the other hand, if the FM/FM PVOR accuracies prove inadequate or sufficient development time is available, the Wide Aperture VOR could be the logical contender for a system, necessitating an airborne receiver modification.

Major efforts to adapt the system to more efficient maintenance philosophies are also included. Previously mentioned efforts such as improving systems quality and the RNAV program may also allow a reduction of the total system size which will further reduce system operation costs.

This plan reflects the requirements recommended in the DOT ATCAC Report (December 1969), the National Aviation System Plan - Ten Year Plan 1973-1982 (March 1972) and the DOT National Plan for Navigation (April 1972). The recommendations of RTCA SC-121, VORTAC Systems Requirements (1980 time period), although not final at this time, also support the rationale of this program. The enclosed RNAV subprograms will validate the recommendations of SC-116E, MOC Airborne Area Navigation System (August 1969). as well as satisfy those requirements stipulated by the FAA/Industry RNAV Task Force in the

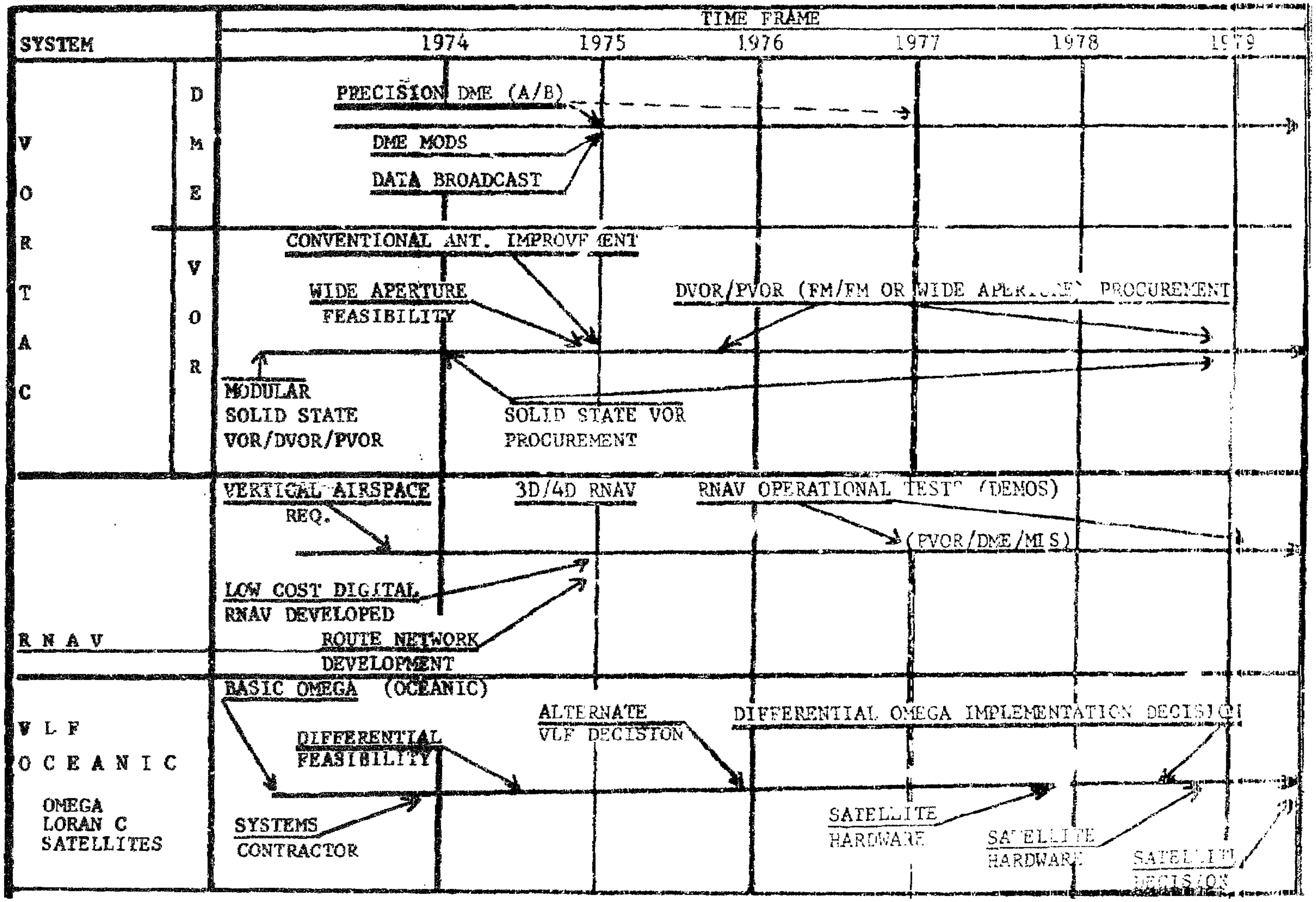
report "Application of Area Navigation in the National Airspace System."

This plan also reflects and will make maximum use of DOD efforts such as the Defense Navigation Satellite System. Overall considerations as specified by the Office of Telecommunications Policy (OTP) will also be reflected in the future efforts. The Area Navigation Program Plan (FAA-ED-04-2) is the other engineering and development document which details this program.

FIGURE 1

ENROUTE NAVIGATION

MASTER PROGRAM CHART



1.1 OVERALL PROGRAM APPROACH

The exact system required to satisfy requirements in a specific area at a specific time period is difficult to determine. Traffic densities airspace allocation rules, airspace equipment requirements, and new aircraft with different flight characterisitcs (etc.) are critical factors which are difficult, if not impossible, to predict. In addition, the effects of ATC Automation on the navigation system requirements are also difficult to determine.

It should also be recognized that the present VORTAC system will be in operation for quite a few years in the future due to the large capital investment and ICAO Agreements. Therefore, efforts will continue to improve the existing equipments to provide an improved service from a standpoint of reliability and coverage.

Long term improvements which, if necessary, will require significant modifications to airborne equipments have also been initiated such as the FM/FM PVOR and the Wide Aperture PVOR. In addition, RNAV concepts techniques and equipments are also being developed. This two-pronged attack will be coordinated and combined at appropriate intervals to insure an optimum result. Operational tests to validate these concepts and equipments will be performed. The retrofit program necessary to continue the VOR system is combined with a maintenance concept project which will result in a more reliable equipment and also one which may be calibrated, monitored and maintained at a lower overall cost. In other words, this would be the first step to automate the maintenance system and therefore allow the current workforce to efficiently handle greater numbers of equipments while holding or improving present reliability standards.

1.2 PROGRAM OBJECTIVES

GENERAL

To provide terminal and enroute navigation systems which can meet the requirements of higher accuracy, greater capacity, better operational flexibility, and those needs associated with the introduction of quiet short haul vehicles.

Specific Objectives

1. Improve VORTAC utility through improved siting techniques and development of less environment sensitive antennas.

2. Provide the VORTAC capability to support reduce route widths for increased system capacity.

3. Provide additional VORTAC channels to accommodate increasing requirements for navigation services.

4. Develop, validate, and demonstrate techniques and principles necessary for the implementation and evolution of RNAV.

5. Develop techniques and equipments to provide navigation capability for Quiet/short haul aircraft.

6. Evaluate the potential application of VLF for aviation applications.

1.3 SUMMARY OF REQUIREMENTS

The requirements of the 04 Program are basically categorized as present and future. This division may be obscure in some cases. Future requirements could be further divided as Upgraded Third Generation and the Advanced Air Traffic Management System (AATMS) efforts.

1.3.1 Present Requirements

In general, the following requirements have been established for the present system. These efforts are also applicable to the Upgraded Third Generation System to some degree.

a) SM-65-34 TACAN Antenna Azimuth Problems, Roughness and Unlock.
b) SM-68-3 Snow/Ice Problems - VORTAC
c) SM-71-6 False DME Lock-On.
d) SC-AFD-67-1 TACAN Heading Effect
e) FS-60-72-1 Evaluation of VLF-RNAV
f) FS-100-71-110 External Reference System Omega
g) FAAR 7031.1 Reduce Separation Standards in Oceanic and Sparseley Populated Areas.
h) RTCA SC-116 MOC Vertical Guidance Equipment used in Airborne Volumetric Navigation Systems
i) RTCA SC-122 - Planning for 50 kHz VOR/ILS Channeling
j) AC-170-12 Implementation of 50 kHz/"Y" Channel for ILS/VOR/DME
k) RTCA-SC-116E MOC - Airborne Area Navigation Systems
l) AC-90-40 Implementation of RNAV

1.3.2 Future Requirements

From a longer range standpoint, which includes the Upgraded Third Generation and Advanced Air Traffic Management Systems (AATMS), the following requirements generalize the efforts in this program.

a) Develop/validate principles and concepts necessary to implement RNAV.

   - o FAA/INDUSTRY RNAV TASK FORCE

b) Improve accuracies of VOR and DME systems to satisfy future capacity demands.

   - o FAA/INDUSTRY RNAV TASK FORCE
   - o ATCAC REPORT - 1969

c) Develop new systems such as VLF to supplement VORTAC system and provide possible base for AATMS applications.

- o DOT, NATIONAL PLAN FOR NAVIGATION
- o AATMS REPORTS, BOEING/AUTONETICS

d) Develop replacements for obsolete equipment using the latest state-of-the-art technique.

- o ATCAC REPORT - 1969
- o THE NATIONAL AVIATION SYSTEM PLAN TEN-YEAR PLAN 1973-1982

1.4 PROGRAM STRUCTURE

The 04 Navigation Program has been divided into 7 Program Elements. Each element in turn has been divided into subprograms as follows:

04 NAVIGATION PROGRAM

041 - VOR Systems

041-305	VOR Maintenance/Sustaining Engineering
041-307	VOR Improved/New Systems Development

042 - TACAN/DME Systems

042-306	TACAN/DME Maintenance/Sustaining Engineering
042-308	TACAN/DME Improved/New Systems Development

043 - VLF/Oceanic Navigation

043-304	VLF Supplement for VOR/DME
043-311	Oceanic Navigation Systems
043-312	Advanced Air Traffic Management Systems (AATMS) Support

044 - Area Navigation (RNAV) System Design

044-326	RNAV Systems Design
044-327	RNAV Airways Network Study

045 - Quiet Short Haul Air Transportation System (QSATS) Support

045-390	Short Haul RNAV Support

046 - Navigation Spectrum Planning

046-620	Navigation Spectrum Planning

047 - Navigation Systems Accuracy and Performance

047-309	Navigation System Accuracy and Performance

1.5 EXPECTED PRODUCTS AND STATUS

1.5.5 During FY-73

041 VOR Systems

- Final report of parasitic ring modification to conventional VOR antennas to improve signal gradient will be completed.

- Engineering model of TACAN shield for DVORs to allow co-location will be delivered. Testing will be initiated.

- FM/FM PVOR ground equipment mods. and airborne receivers will be delivered. Field installation will be initiated at major terminals with DVORs for operational testing.

- Feasibility model of Wide Aperture VOR factory tests will be completed.

- Self supported VORTAC shelter engineering model contract will be awarded.

- Final report on 50 kHz spacing effects on in service A/B equipments will be completed. Advisory Circular, if necessary, will be initiated.

- Ground Equipment modifications for 50 kHz spacing for the majority of ground equipments shall be completed. Modifications for unique installations will continue.

- Feasibility model of 5 Bay antenna for conventional VORs will be delivered. Testing to determine it's practicality for high gradient application will be initiated.

- The study of the application of high gradient antennas will continue. Interim reports will be completed.

- A computer model of siting effects and reflections will be initiated. This model will aid in the siting of new sites, determine proper corrective action for current facilities, and aid in the decision to upgrade a problem site to a DVOR or PVOR.

042 TACAN/DME Systems

- Factory testing of TACAN antenna modifications and techniques to reduce weather induced outages and site polarization effects will be initiated.

- Joint DOD/FAA testing of feasibility model electronically modulated antenna will be complete. Decision for further testing by FAA independently will be resolved.

- Factory testing of "Y" channel TACAN antenna and ground equipment modifications will be initiated. (Engineering Model)
- Field evaluation of YN-104 TACAN antenna at variable heights will be initiated to determine reduction of siting effects.

- Factory testing of TACAN capacity increase modifications will be intiated. (Engineering Model)

- Final report on feasibility and utility of Data Broadcast modifications to TACANs will be complete. Decision to initiate development of engineering model of data broadcast modifications will be resolved.

044 RNAV System Design

- Pilot performance Phase II tests using RNAV displays will be complete. Preliminary Phase II Report issued. Tests will continue.

- Preliminary studies and flight test reports on (vertical) VNAV will be delivered.

- Preliminary studies for 3D/4D RNAV engineering model development will be delivered. Procurement of hardware will be initiated.

- Initial Report defining RNAV enroute methodology will be completed. Low Altitude/terminal effort will be initiated.

- ATC real time/fast time simulations will be initiated.

- Cost/benefit analysis will be initiated.

045 QSAT System Support

- QSAT Navigation requirements analysis will be completed.

- Evaluation of DME/DME, VOR/DME and Loran C for QSATS operations will be completed.

046 Frequency Spectrum Planning

- Testing to develop spatial/spectral criteria for VORTAC frequency assignment for 50 kHz/"Y" channel will be initiated after development of the automated Frequency Spectrum Computer Program.

047 Navigation System Accuracy and Performance

- Efforts will be initiated to determine route widths requirements to satisfy the estimated range of aircraft densities of the future using inter and intra navigation relationships.

- Efforts will be initiated to develop A/B capability to validate current system performance and future developments. Low altitude data is lacking.

1.5.2 <u>During FY-74</u>

041 VOR Systems

- o Final Report, 5 Bay antenna development for high gradient applications at conventional sites will be completed.
- o Final report of TACAN shield for DVOR sites will be completed.
- o Final installations of FM/FM PVOR will be completed. Operational demonstrations and tests will be initiated.
- o Wide Aperture PVOR feasibility model will be delivered. Technical evaluation will be initiated.
- o Self-Supported VORTAC shelter will be delivered. Test will be initiated and final report completed. Field operational tests will be initiated.
- o Solid State VOR/DVOR/PVOR development will be initiated including remote sensor and automated maintenance concept techniques.
- o Development, test and evaluation of all 50 kHz channel modifications will be completed.
- o Study of High Gradient antenna applications will continue Interim recommendations will be completed.
- o VOR Reflections/Siting Computer Model will be completed. Validation testing will be initiated and completed.

042 TACAN/DME System

- o Prototype TACAN antenna modifications for reducing weather outages and site polarization effects will be delivered for field installation. Operational evaluation will be initiated.
- o Field evaluation of improved TACAN antennas with variable height test will continue to determine improvement in siting problems. Interim report will be issued.
- o <u>Engineering model</u> TACAN antenna and "Y" channel equipment modifications completed. Factory test of <u>prototype</u> antenna and equipments initiated.

- o Electronic Modulated Antenna contract initiated for FAA monitor maintenance requirement modifications, if necessary.

- o Evaluation of TACAN capacity increase modifications will be initiated and completed.

- o Development of DME remote sensor and automated maintenance concept techniques will be initiated.

- o Development of precision DME for CAT. III/V/STOL/RNAV applications will be initiated, if necessary.

- o Data Broadcast modifications will be initiated, if necessary.

<u>043 VLF/Oceanic Navigation Systems</u>

- o Evaluation of the differential Omega feasibility model will continue.

- o Investigations of Omega signal transmission will continue. Preliminary recommendations as to the practicality of IFR usability will be issued to agency operational services.

- o Representative Omega receiver tests will be continued. Interim report will be issued analyzing unique, desirable and/or undesirable characteristics of tested equipments. Preliminary reports establishing feasibility for low cost, supplemental, and/or oceanic applications of Omega/VLF will be issued.

<u>044 RNAV Systems Design</u>

- o Final report for <u>enroute</u> RNAV network development will be completed. Low altitude <u>terminal</u> studies/modeling will continue.

- o Pilot performance Phase II final report will be issued. Tests will continue.

- o 3D/4D technical and operational tests will be initiated. Interim report will be issued.

- o Interim report on VNAV will be issued. Studies and flight tests will continue.

- ATC real time simulations will continue. Interim reports will be issued. ATC fast time simulation will be completed and preliminary report issued.

- Cost/Benefit analysis preliminary report will be issued.

045 QSAT System Support

- Development of navigation system to satisfy unique QSATS requirements will be initiated.

046 Navigation Spectrum Planning

- Spatial/Spectral criteria for frequency assignment of VORTAC 50 kHz/"Y" channel implemenation will be continued. Preliminary report will be issued.

047 Navigation System Accuracy and Performance

- Cost/Benefit analysis for route width reduction will be initiated applying error budget, ATC automation, operational, etc., constraints.

- Initial guidance and A/B test equipment will be delivered for initial validation of PVOR performance, DME/DME performance, current system accuracy determination, determination of error budget component impact, etc. Instrumentation and data reduction efforts will continue.

2.0 PROGRAM DESCRIPTION

The 04 Program contains 7 program elements which in turn contain 10 subprograms. The following is a breakdown of the effort at the project level.

2.1 VOR SYSTEMS

A. Program Element Structure

041 VOR Systems

041-305 VOR Maintenance/Sustaining Engineering

041-305-013 Siting Improvements

- o Multiple Bay Antennas
- o Propagation Modeling & Analytical Studies
- o Shielding/Screening
- o Tower Installations

041-305-023 Maintainability Improvement

- o Solid State Transmitter
- o Modular VOR/DVOR/PVOR
- o Improved Ground Test & Support Equipment
- o Self-Support Shelter

041-307 VOR Improved/New System Development

041-307-013 Channel Expansion

041-307-023 PVOR Development

- o Wide Aperture Development
- o FM/FM Operational Tests

041-307-033 VOR Systems Validation

- o Low Altitude/Precision Flight Test Capability Development

B. Background

Increasing traffic forecasts for the post 1980 period indicates that a significant increase in VOR reliability and accuracy will, in all probability, be necessary in a number of high

density areas. To meet this demand, this program element is developing precision NAVAIDs in conjunction with avionics and route structure advances in the RNAV area. In addition, the probability is great that the VOR system will continue to be the primary navigation system well into the future. It will, therefore, be necessary to upgrade and/or replace a large number of tube type VORs in the near future. It is, therefore, a major concern of the FAA to replace or retrofit these equipments with highly reliable, solid state components which have automatic (semi) error sensor, control and transmission capability.

C. Objectives

1. Improve the antenna systems to minimize multi-path and signal coverage problems.

2. Improve the monitor system to reduce maintenance and calibration problems.

3. Develop modifications to allow channel doubling and determine effects on present receiver operation.

4. Develop and evaluate new precision VOR system in support of future requirements.

5. Establish a capability to measure current system performance at low altitude and the new precision equipments.

6. Develop new maintenance capabilities to minimize operational maintenance costs and improve system reliability.

2.1.1 041-305 VOR Maintenance/Sustaining Engineering

2.1.1.1 041-305-013 Siting Improvements

It is estimated that a significant percentage of present VORs (approximately 25%) are currently restricted due to poor signal quality which will be a critical RNAV problem. A large percentage are also impaired to a lesser extent. It should also be noted that the growth of vegetation, new building construction and the interference of large aircraft on airport-located VORs are causing additional problems.

Most new VORs will be of the airport-located (TVOR) variety and, therefore, will be difficult to site. The majority of VOR upgraded in support of RNAV will probably include facilities located in densely populated areas where resulting siting problems are inevitable. It is from this viewpoint that a number of VORTAC system siting projects are presently active or are planned for the near future.

o <u>Develop antennas</u> for the conventional VORs which minimize propagation toward the ground. These antennas are sometimes referred to as "High Gradient" antennas. Presently, two such antennas are presently under development. There are three basic applications projected for this approach:

1) Sites which are mountain top located (no counterpoise/ground mounted) and are therefore, highly affected by snow, ice and new vegetation growth.

2) new sites which would require extensive site preparation including leveling of a mountain top or clearing trees.

3) existing sites with new reflecting objects or new sites in congested areas.

o <u>Propagation Modeling and Analytical Studies to Apply Siting Fixes</u>

In order to apply the results of the preceding efforts, criteria must be developed to interpret the empirical data obtained in evaluating the fixes. Projects to isolate the offending reflecting surfaces will also be initiated to determine their location and thereby affect the optimum solution to the problem.

To coordinate the above efforts from a system standpoint, a VOR Systems Siting Contract will be initiated combining the responsibilities for:

1) Analytical efforts to determine the optimal method of solving the different siting problems.

2) The empirical data collection and reduction necessary to evaluate and test different siting solutions.

3) A quick reaction capability to solve field problems which occur during the course of the fiscal year which are unforeseen.

o <u>Shielding, Screening, etc. of Reflecting Objects.</u>

This effort will allow the development of techniques and materials to minimize the effect of isolated reflecting surfaces. A primary output of the effort will allow the co-location of the DVOR with TACAN facilities which must presently be separated due to the reflection problem. This may also be an economical method of eliminating minor reflected problems at existing, non-critical, conventional VORs.

o <u>Installation of antennas on towers.</u>

This concept would complement the previously mentioned antenna improvement projects. The added height will enable clearance of obstructions such as hangars, large aircraft, etc. This technique was successful at Dallas utilizing a DVOR. This concept is recognized to be costly which will severely limit field implementation to "must have" type installations.

2.1.1.2 <u>041-305-023 Maintainability Improvement</u>

o <u>A Modular Solid State VOR/DVOR/PVOR</u>

It is the intent of SRDS to develop a modular solid state PVOR/DVOR/VOR for any future implementation plans. Approximately 115 new VORs are projected for the next 10 years. These solid state models are planned to be available for installation by early 1975 to fulfill the operational requirement stated in the 10 Year Plan and re-justified in recent calls for estimates. The modularity attribute will consist of the capability to economically convert any of these models to a precision or doppler model from a conventional VOR. The logistics problems should also be minimized.

In addition to the new equipment requirements, the following additional considerations are also factors for implementing solid state models:

1) as replacement for aging tube type transmitters and,
2) as replacement for sites to be relocated due to RNAV requirements.

The rationale is that the solid state model will require significantly less maintenance and calibration thereby reducing maintenance costs. Recent RNAV network studies have indicated that nearly one half (½) of the existing sites could be eliminated if all users were RNAV equipped. Unfortunately, the present air route structure must also be maintained for an interim period. Due to this constraint, facilities cannot be relocated without significant impact on normal (existing) operation. In addition, the initial RNAV capability would probably be installed in the high density terminal (or corridor) areas which would necessitate a PVOR/DVOR. Therefore, an increase in the total number of VORs would be necessary during this period.

In summary, the actual number of new systems purchased and implemented will be a function of many factors such as (1) the traffic density (with the resultant necessity to increase NAVAID accuracy), (2) the availability of other systems such as Omega, (3) and the demands of new user requirements such as V/STOL operations. The solid state VOR is basically justified from the immediate operational need of TVORs and the maintenance requirement of a solid state transmitter modification for reliability reasons.

o <u>Improved Ground Test and Support Equipment</u>

Simultaneous with the development of the highly reliable solid state VOR, test points for automatic sensors, data storage, and devices for the transmission of monitor/test point devices will be included in the basic design. The feasibility, practicality and use of multi-ground monitors to minimize airborne testing will also be included.

o <u>Self-Support Shelter</u>

In order to minimize the cost of VORTAC shelters necessary for a few problem sites, self-supported styroform, urethane, and/or fiberglass-urethane engineering models will be purchased and evaluated as to their affect upon radiated signals and ease of construction. Techniques which entail foaming (in place) the use of panels or blocks are being considered.

2.1.2 041-307 VOR Improved/New Systems Development

2.1.2.1 041-307-013 50 kHz Channel Spacing

Projects are presently underway to reduce VOR channel spacing to 50 kHz from the present 100 kHz. These additional channels are necessary to implement new ILS and TVOR facilities. New VORTACs for additional airways on high density routes will also use these additional channels. Projects to evaluate and test the necessary ground modifications and the affect on present receivers will be continued.

2.1.2.2 041-307-023 PVOR Development

o FM/FM PVOR

As an improvement to the conventional VOR, the agency has developed a Doppler VOR (DVOR) as a fix for difficult sites. This equipment has proved fairly successful in allowing the commissioning of previously unacceptable sites and increasing the usable coverage of others. This concept also allows the use of unmodified conventional VOR receivers. An additional improvement (FM/FM PVOR) has also been developed and tested which completely eliminate amplitude modulation problems but requires a modification of airborne receivers. This FM/FM VOR also requires the conversion of a conventional VOR to a DVOR and results in the full attainment of its inherent capability. The conventional AM signal is also retained to satisfy compatibility requirements for users of the non-modified receivers.

o Wide Aperture PVOR

Another contender for the Precision VOR (PVOR) concept is the Wide Aperture (Digital) VOR. Since the FM/FM technique requires an airborne modification and a DVOR conversion necessitating a large counterpoise and approximately 50 antennas, it is reasoned that the maximum improvement of the VOR system should be realized for any avionics/ground retrofit program. To accomplish this objective, a development program for the Wide Aperture VOR has been initiated so that a choice between this

concept and that of the FM/FM technique can be made with a minimal risk sometime beginning in FY-76. The benefit of minimizing siting problems is equal to the accuracy improvement in this approach.

2.1.3.3 041-307-033 VOR Systems Validation

- Low Altitude Flight Test Positional Measurement

  Present flight test techniques do not allow sufficient accuracy necessary to measure signal errors at low altitudes. SAFI flight test data is not available below 8000 ft. due to a multiple DME position resolution requirement. Also, the collection of data by theodolite is not practical at ranges beyond 10 miles due to visual limitations. The present method of aircraft positional measurement by ground point methods is obviously inaccurate, due to excessive pilotage errors. Therefore, two distinct requirements are emerging which necessitate the development of an accurate R&D aircraft positional measurement capability.

  1) The present VORTAC system must be evaluated to determine its capability to satisfy future requirements. This will require a low altitude flight test of a significant number of field sites to establish the true state of the system due to siting factors. This cannot be established at NAFEC alone.

  2) The development of improved and precision NAVAIDs has or will surpass the present flight check capability. Future flight testing must be performed in an operational environment remote from NAFEC's precision range. Examples of these efforts are the eventual FM/FM PVOR operational tests, the RNAV Flight Demonstration tests, and the Omega/VLF quasi-operational tests. In addition, this capability may also be necessary to evaluate the MLS and metering and spacing efforts requiring curvelinear approaches. Present error budget assumptions (statistical independence of errors and a normal distribution) are being challenged and if proved false will significantly affect present NAVAID development. This instrumentation will allow the determination of the validity of these assumptions.

2.2 042 TACAN/DME SYSTEMS

A. Program Element Structure

042-306 TACAN/DME Maintenance/Sustaining Engineering

042-306-013 Siting/Weather Improvements

- o RTA-2 Antenna/Radome Modifications
- o False Lock-On Modifications (Continued)
- o YN-104 Eval./Tower Tests
- o Capacity Measurement and Interrogator Survey

042-306-023 Maintainability Improvements

- o EMA Development
- o Solid State Component Modifications
- o Error Sensing & Remoting Modifications

042-308 TACAN/DME Improved/New Systems

042-308-013 Siting-Weather Improvement

042-308-023 Flexibility/Precision Development

- o Data Broadcast
- o Precision DME (Cat. III DME/DME)

B. Background

As with the VORs, increased traffic loading in certain areas is predicted to require greater capacities for DME ground station. This requirement, as well as an increase in available channels and minimization of siting problems, is included in this program element. Modification of the system to support RNAV implementation such as data broadcast are also contained in this effort.

C. Objectives

1. Minimize siting and weather problems of existing systems.

2. Increase capacity and precision of equipments as necessary.

3. Develop modifications to existing equipments to allow channel doubling and determine effect on current receivers.

4. Develop modification to increase the reliability and availability of the system.

2.2.1 042-306 TACAN (DME) Maintenance/Sustaining Engineering

2.2.1.1 042-306-013 Siting/Weather Improvement

As with the VORs, siting problems are evident and must be improved for present operations. RNAV requirements also necessitates the assurance of proper DME operations. Solutions to most of these problems are already underway. Vertical pattern improvements, polarization elimination, snow/ice sensitivity, and false lock-on problems are the subject of existing contracts. Funding for evaluating these developments is budgeted in subsequent years. A remaining effort in this area is the height tests which may be initiated to solve extreme siting problems, if necessary. In order to coordinate the efforts as well as perform the evaluation and analysis necessary for a systematic approach to this problem, a TACAN/DME Systems Contractor will be established. A quick reaction agreement will also be included to aid in the solution of unscheduled field problems.

2.2.1.2 042-306-023 Maintainability Improvements

Unlike the VORs, the TACAN equipments are relatively new equipments. Their replacement is not presently contemplated although the development of a modular solid state model is a possibility if a DME/DME RNAV concept for V/STOL is adopted. Again, the demand factors shall dictate the development period and level of effort.

The development of an electronically modulated antenna (EMA) having potentially better signal radiating characteristics and reliability is also being considered for the future.

Present DOD efforts in this area are being monitored and airborne measurement support will be furnished. If promising, a DOD/DOT agreement has been reached to transfer development of these devices (purchased by the DOD) to the FAA. Further development peculiar to the FAA such as monitoring will then be performed.

2.2.2 042-308 Improved/New TACAN/DME Developments

2.2.2.1 042-308-013 Expansion/Capacity Development

- "Y" Channel Development

  Concurrent with the 50 kHz VOR efforts, TACAN/DME channel doubling efforts are presently underway. Evaluation and analysis of the required modifications will be performed.

- Increased DME Capacity

  The capacity of the DME is presently being improved under an existing contract. This modification coupled with new airborne interrogators with lower interrogation rates will easily allow an increase in capacity well above the 350 aircraft requirement (RTCA) necessary for the next decade.

2.2.2.2 042-308-023 Flexibility/Precision DME Development

- A precision DME for Cat. III operations will be initiated if NAFEC Cat. III testing indicates that the present solid state Terminal DME is not satisfactory. If necessary, airborne DME improvement programs will be initiated, since ground DME equipment improvements have reached a point of diminishing returns.

  The V/STOL DME/DME effort may also require the initiation of this program which would require the development of airborne DME modifications.

- The Data Broadcast capability is already a part of an FY-72 procurement ("Y" Channel Equipment). This capability will be formally initiated on 31 January 1973 if present studies, RNAV Tasks Force results, and RTCA Committee requirements so indicate. Further funding for the airborne components for this function is also planned.

2.3 043 VLF/OCEANIC NAVIGATION SYSTEMS

A. Program Structure

043-304 VLF Supplement VOR/DME

043-304-013 VLF Navigation System Analyses

- VLF Navigation System Study
- VLF Omega Signal Monitor
- VLF Noise Instrumentation
- Noise Cancellation Antenna

043-304-023 VLF Equipment Evaluation

- Low Cost Omega Receiver Evaluation
- Global Navigation Model GNS-200 Evaluation

043-304-033 Differential Omega Development

- Differential Omega - Feasibility Model
- Differential Omega - Operational Model
- Differential Omega - Implemenation

043-311 Oceanic Navigation Systems

043-311-013 Loran-A Replacement System

- 3.4 kHz Omega Evaluation
- Civil Omega System
- Loran-C Navigation

043-311-023 Self-Contained Systems

- Oceanic Separation Standard Reduction

043-312 Advanced Air Traffic Management System Support

043-312-013 VLF Systems Investigations

- Low Cost VLF (IPC)

043-312-023 Satellite Navigation Experiments

- Computer Model

B. Background

There is a need to reduce aircraft separation standards on oceanic routes in order to increase the number of aircraft that can be accommodated on those route. Navigation systems which may lead to the accomplishment of this purpose will be developed and evaluated. A more specific purpose is to investigate Omega as a replacement for Loran-A.

The VOR/DME system does not provid adequate signal coverage to significant areas within and near the continental U.S. and Alaska. Specifically, VOR/DME coverage in mountainous areas, and off the coast line at low altitudes is not complete. VTOL and STOL aircraft are especially affected in these areas. The provision of navigation services as a supplement to VOR/DME with VLF techniques will be investigated and conclusive determinations will be reported.

The possible application of VLF and satellite navigation in the "Advanced Air Traffic Management System" will be examined.

In order to provide necessary personnel, facilities, and services for the FAA to reach a timely conclusion on the potential value of VLF navigation, a contract will be awarded for the provision of technical assistance. The contractor will develop and evaluate several of the items included in projects described in this plan.

C. Objectives

The objectives of this program are:

1) Evaluate VLF navigation as a supplement to the VOR/DME system and thereb limit the necessity to expand the VOR/DME system.

2) Evaluate the utility of VLF navigation on oceanic routes as a replacement for Loran-A as the military requirement for Loran-A decreases.

3) Investigate applications of VLF and satellite navigation for use in the Advanced Air Traffic Management System (AATMS).

4) Evaluate the possible reduction of oceanic route separation standards through the refinement of the data base on existing navigation systems.

2.3.1 043-304 VLF Supplement of VOR/DME

Included in this subprogram are three projects:

2.3.1.1 043-304-013 VLF Navigation System Analysis

The objectives of this project are to provide data on VLF signal reception, signal integrity, VLF band noise, and the configuration and operating parameters of an optimum VLF air navigation system.

- VLF Navigation System Study

  A study will be made to determine the optimum VLF navigation system for the domestic U.S. This study will follow an assessment of Omega and VLF communication signal navigation capabilities and will include transmitter locations, frequencies, radiated power, and data rate which would be most suitable for aviation use. This study will also include operational advantages and disadvantages and the economic considerations of such a system. If Omega does not meet aviation requirements, but the VLF technique does solve navigation problems, it may be desirable to consider a VLF system designed especially for aviation use.

- VLF/Omega Signal Monitor

  An investigation of a method for the FAA to use as an operational monitor of VLF/Omega navigation signals will be conducted. If VLF or Omega signals result in operational use by aircraft in the air traffic system, the FAA will need real time data on the status of these signals; similar to the information necessary for monitoring signals of VOR/DME and ILS facilities. The investigation will define the best way to provide the required information to the ATC system. Full consideration will be given to extensive VLF signal monitoring presently conducted by other government agencies.

- VLF Noise Instrumentation

  Instrumentation to be used to investigate VLF band noise found in aircraft will be procured and evaluated. The need exists to find ways to reduce VLF noise if VLF navigation is to be used aboard a variety of aircraft which range from general aviation to transport types. Reduction of noise coupled into the VLF antenna from the aircraft will increase the signal to noise ratio in the VLF receiver. In order to properly evaluate noise reduction techniques or devices, instrumentation that can adequately measure and define VLF band noise will be needed. It is expected that existing test units can be configured as a system to accomplish this task.

- Noise Cancellation Antenna

  A VLF antenna system which uses top and bottom mounted E-field antennas on an aircraft may be useful in eliminating the detrimental effects on E-field noise. Received VLF signals are 180° out of phase at the top and bottom of an aircraft. Noise currents induced in the fuselage by a discharge from an extremity of the aircraft will be the same at the lowr and upper antenna locations. Thus, equal in-phase noise currents will be generated in the two antennas. By feeding the antenna outputs to a device which will shift one output by 180° and add it to the other antenna output, the noise signals will cancel and the VLF signals will add and thus improve the resultant signal to the receiver. This system could provide, at a low cost, the advantages presently available with the relatively expensive crossed-loop antennas. This technique could be especially valuable in general aviation use of Omega or VLF, where a crossed-loop antenna is too expensive.

2.3.1.2 043-304-023 VLF Equipment Evaluation

The objective of this project is to evaluate the performance of representative low cost VLF and Omega airborne units to determine suitability for use by general aviation.

o <u>Low Cost Omega Receiver Evaluation</u>

Low cost airborne Omega receivers will be procured, but not developed, by the FAA for evaluation. These units will be procured and evaluated as they become available.

o <u>Global Navigation Model GNS-200 VLF System Evaluation</u>

On-going evaluations of the GNS-200 equipment will be complemented by further flight evaluation to determine the suitability of this equipment for possible IFR use. The GNS-200 unit owned by the FAA will be used in this evaluation aboard an FAA aircraft. This evaluation is intended to provide information for FAA operating services in the definition of operational advantages and disadvantages in the GNS-200 techniuqe and equipment.

2.3.1.3 <u>043-304-033 Different Omega Development</u>

The objective of this project is to develop and evaluate the differential Omega technique to a point where it could be implemented as an operational navigation system.

o <u>Differential Omega - Feasibility Model Development and Evaluation</u>

A feasibility model differential Omega system will be developed and evaluated to determine the optimum operating parameters of this technique in air navigation. The equipment will be sufficiently flexible to permit tests with a wide variety of operating schemes. The usable coverage area of differential Omega will be defined with the feasibility equipment. An output of this evaluation will be data for use in the specification of the follow-on operational type differential Omega system.

o <u>Operational Differential Omega System Development and Evaluation</u>

This effort will follow the differential Omega evaluation by FAA and will involve development of an operational type differential Omega System. In the operational system, an area of the U.S.

will be covered by signals from three differential Omega ground stations operating full time. Six aircraft, appropriately equipped, which normally fly in the test area, will use the system in an operational manner for approximately 11 months. If this effort is successful, and interest in differential Omega is adequate, then an actual implementation plan will be completed.

- Differential Omega Implementation Plan

  A plan for the systematic implementation of a differential Omega system will be developed. Work on this plan will be started only after some success with the operational differential Omega system. The plan will provide FAA management with a realistic data on the technology, operating techniques, costs locations, and schedule involved in the installation and use of differential Omega. This plan can be applicable to Omega or any other VLF navigation system, such as that system envisioned in project number 043-304-013.

2.3.2 043-311 Oceanic Navigation Systems

Included in this subprogram are two projects.

2.3.2.1 043-311-013 Loran-A Replacement System

The objective of this project is to evaluate VLF Navigation as a potential replacement for the Loran-A System. The military requirement for Loran-A will end at the close of 1974. An FAA requirement remains to update Doppler Systems on oceanic routes with an external reference system; Loran-A fulfills that requirement at present.

- Evaluation of 3.4 kHz Omega Difference Frequency Navigation

  The 3.4 kHz Omega difference frequency is derived artifically from two basic Omega signals; (13.6 kHz - 10.2 kHz = 3.4 kHz). This technique shows promise of reducing the dependence of Omega on predictions of ionosphere height. The Naval Electronics Laboratory is designing a 3.4 kHz experimental Omega receiver for the FAA; it

will be evaluated for use in bounding the errors of Doppler systems used on oceanic routes. The 3.4 kHz receiver will operate independently with no input from the Doppler equipment.

- Civil Aviation Airborne Omega System

  The purpose of this effort is to assemble a single airborne unit that can provide aircraft navigation in oceanic, enroute and terminal areas.

- Loran-C Navigation

  Developments in airborne Loran-C navigation systems by private industry and other government agencies will be closely monitored to assess possible use by civil aviation. No developments or evaluations of Loran-C equipment for oceanic applications are presently planned.

2.3.2.2 043-311-023 Self-Contained Systems

The objective of this project is to determine whether oceanic route separation standards can be reduced based on performance of existing self-contained navigation system. New developments in self-contained systems will be monitored for potential applications in civil aviation.

- Oceanic Separation Standards Reduction

  A study of the impact of the increased use of inertial navigation on the oceanic air traffic situation will be carried out. This study will use data collected over several years by users of INS to determine whether route separations can be reduced, and it will test the validity of collision risk models developed recently. When actual data shows the degree of validity of collision risk models, the value of models in separation planning by the U.S. and other countries in ICAO will be established. Separation reduction goals are contained in the DOT National Plan for Navigation, April 1972.

2.3.3 043-312 Advanced Air Traffic Management System Support

Included in this subprogram are two projects:

2.3.3.1 043-312-013 VLF Systems Investigation

The objective of this project is to determine the suitability of VLF navigation as the system for use in the Advanced Air Traffic Management System (AATMS).

Omega is one of the navigation systems under consideration for use in the AATMS. Accomplishment of this project will lie in Omega evaluations conducted in subprograms 043-304 and 043-311. Aspects of those evaluations which may bear on selection of Omega for AATMS use will be assembled in a separate document for ultimate use by FAA and DOT management.

2.3.3.2 043-312-023 Satellite Navigation

The objective of this project is to evaluate satellite navigation for possible use in the AATMS.

c Navigation Systems Computer Model

The Transportation Systems Center has awarded a contract for a working computer model of satellite, inertial, Doppler and Omega navigation systems. The model will permit theoretical study of any of these navigation systems through parametric analysis. Naval Research Laboratory will exercise the model for the FAA on a Computer Data Corporation model CDC-3800 computer. The model will be used to investigate the feasibility of various navigation systems applications before beginning new studies or hardware development efforts. Since the flexibility of the model will allow almost any conceivable system parameters, it will be possible to investigate systems established by other agencies, other countries, or by private companies; therefore, expected test results will be available before actual tests begin.

- Satellite Navigation Experiments

  Experiments in satellite navigation will be carried out in cooperation with surveillance ranging experiments. It is planned to conduct surveillance ranging experiments with the ATS-F and the Aeronautical satellites. Experiments will be designed to meet the ranging and communication specifications of the individual satellites. Two types of navigation tests are anticipated (1) relay of surveillance positions from the control center to the aircraft via communication link, and (2) position determination in the aircraft by ranging to two satellites, and by having knowledge of satellite ephemerides This effort is scheduled to be initiated fairly late in this program.

2.4 AREA NAVIGATION (RNAV) SYSTEM DESIGN

A. Program Element Structure

044 RNAV System Design

044-326 Area Navigation Systems Design

044-326-013 RNAV System Studies and Program Coordination

044-326-023 Route Development

044-326-033 Avionics Standards

044-326-043 Upgraded Third Generation Compatibility

044-326-053 Economics Benefit/Cost Analysis

044-326-063 Low Cost RNAV System Verification

044-326-073 Unique RNAV Requirements

044-327 RNAV Airway Network Study

B. Background

Although this effort is part of the overall Navigation Program, a separate plan is presently being prepared. This is due to the large impact of this effort on other segments of the agency; namely Air Traffic Control. An FAA/Industry RNAV Task Force has published a report, Application of Area Navigation in the National Airspace System. This report will be the basis for an

Area Navigation Program Plan (FAA-ED-04-2). Table I indicates the funding levels deemed necessary to support this effort.

C. Objectives

1) Support implementation and demonstrate the utility of area navigation routes and procedures.

2) Verify and establish avionics standards

3) Provide low cost digital RNAV capability to broaden RNAV implementation to all classes of aviation users

4) Determine area navigation system requirements to satisfy upgraded third generation and advanced air traffic management

5) Establish cost/benefit to airline user and ATC system

2.5 (045) QUIET SHORT HAUL AIR TRANSPORTATION SYSTEM (QSATS)

A. Program Element Structure

045-490 Short Haul Navigation Support

045-490-013 Short Haul RNAV Support

B. Background

A detailed plan describing the QSATS program including timing and funding requirements may be found in the Quiet Short Haul Air Transportation System Development Plan.

C. Objectives

1) Support the development of techniques and equipment to provide area navigation capability for Short Haul application.

2.5.1 045-390 Short Haul Navigation Support

2.5.1.2 045-490-013 Short Haul RNAV Support

This effort is concerned with the investigation and establishment of standards for airborne RNAV hardware and software techniques integrated with standard and improved VOR/DME, DME/DME, and/or VLF techniques specifically for Short Haul applications.

2.6 FREQUENCY SPECTRUM PLANNING

A. Program Element Structure

046 Frequency Spectrum Planning

046-620 Frequency Spectrum Planning

B. Background

The 50 kHz/"Y" channel effort has resulted in a new dimension in complexity for the assignment of VORTAC/ILS channels. Empirically established guidelines are no longer valid due to effects of spurious emissions such as harmonics on equipments designed for 100 kHz operation. Modifications have been developed for most ground station equipment to minimize these problems. Airborne equipments are now being tested to measure the impact of this change on equipments already in service and to establish new avionic standards.

C. Objectives

1) Develop spatial/spectrum criteria to allow optimal 50 kHz "Y" channel VORTAC assignments.

2.6.1 046-620 Frequency Spectrum Planning

- o Empirical data to determine effects of 50 kHz/"Y" channel spacing on current airborne receivers will be collected and analyzed.

- o Spatial and spectrum criteria will be established to determine optimal frequency allocation with minimum disruption to current frequency assignments.

2.7 NAVIGATION SYSTEM ACCURACY AND PERFORMANCE

A. Program Element Structure

047 Navigation System Accuracy & Performance

047-309 Navigation System Accuracy and Performance

047-309-013 Navigation Accuracy Requirement

- o Route Width Definition
- o NAS Cost/Benefit Analysis

047-309-023 Navigation System Data Collection and Error Validation

- o Guidance System Development
- o VORTAC Measurement Requirements
- o VLF Measurement Requirements

B. Background

Solution of the capacity problem unilaterally is a high risk approach, extremely, disruptive during system changeover, and usually prejudicial to some user groups.

Therefore, it is the intent of this subprogram to develop the NAS Navigation System fully recognizing these constraints.

C. Objectives

1) Define navigation system requirements by relating overall ATC system requirements such as capacities and route densities to route widths and navigation accuracies.

2) Establish a navigation error data collection capability with highly accurate guidance system.

3) Coordinate NAV and ATC system development through cost/benefit analysis to allow timely and economic solutions of the agency capacity problem.

2.7.1 047-309 Navigation System Accuracy & Performance

In order to provide for a systematic development of new and/or improved navigation systems, assure compatibility between various navigation systems and other NAS system elements, and provide certain backup data that is necessary for many of the individual navigation system plans, certain new efforts will be initiated to complete the overall objectives of the navigation system Program Plan. These program elements are outlined below.

2.7.1.1 047-309-013 Navigation Accuracy Requirements

In the past, route widths have been related to twice the 2 sigma navigation accuracy. The interaction of navigation and surveillance has not been considered either for defining route widths or for required values of routes widths defining both navigation and surveillance accuracies.

The objective of this project is to establish the relationship between route width requirements and navigation and surveillance accuracy requirements. It is first necessary to determine a suitable criterion for relating navigation and surveillance accuracies which can be physically related to other considerations such as controller workload and automation requirements. Frequency of intervention appears to be a key parameter that can be used as the criterion.

A simulation will be developed to determine for specific types of navigation and surveillance systems and what the frequency of intervention will be for various route widths under operational conditions. These results can then be used to fix the maximum acceptable frequency of intervention based on controller workload, automation requirements, etc. For a fixed level of intervention, sensitivity curves can be generated to determine the relative effectiveness of navigation and surveillance to satisfy specified in-track, lateral and vertical separation requirements. This same procedure can be used to evaluate the relative effectiveness of different navigation systems, different surveillance systems, automation requirements, etc. It would provide the much needed framework for relating route widths to navigation accuracy and other system accuracies for different time periods and capacity requirements. The results would be a number of sensitivity curves which could be used to specify system requirements for different levels of demand.

- <u>Definition of Route Width Requirements</u>

  A number of major navigation programs have been initiated based on the recommended route width requirements of RTCA, the Area Navigation Task Force and other planning groups. Since the reduced route width requirements will have a major impact on navigation and other ATC system element development, it is very important to establish what realistic route width requirements are.

The objective of this task is to establish the methodology for defining widths based on airway travel demand (capacity). This effort will lead to a realistic definition of route widths for various airspace types, geographical locations, RNAV and VORTAC routes. IFR peak day and other historical traffic data, and forecasted demands will be used to generate aircraft densities along typical route segments. The route densities will be used together with airspace availability, aircraft performance considerations, user mix (a/c performance and navigation types) runway configurations, operational procedures, airline schedules, and interface constraints with MLS to recommend in-track, cross-track and vertical separations. Since forecasted demands are subject to constraint variation, the output will be design curves relating capacity and route densities to separation standards for various time periods.

o Cost Analysis

The sensitivity data provided in the first task will provide valuable information to evaluate candidate systems and define systems requirements. A second essential task that is necessary to provide information for system evaluation and design purposes is to perform cost analyses. Several of these analyses are currently underway in other navigation programs.

The objective of this program element will be to coordinate existing cost analyses and provide additional effort where required to:

1) Evaluate navigation system and other automation costs. This data together with the accuracy sensitivity data will provide a basis for evaluating the overall effectiveness of candidate system elements for satisfying reduced route width requirements.

2) Evaluate total system costs for implementing new navigation systems or improving present systems. Ground facility, airborne equipment, maintenance, and other essential elements will be included.

3) Evaluate cost effectiveness of candidate navigation systems. Many of the reduced route widths can be achieved by several systems. Where this is the case, it should be determined which system is the most effective for satisfying the requirement. Both cost and sensitivity analyses will be used for this purpose.

4) Evaluate user benefits. An extensive user (economic) benefit analysis is already underway for the RNAV program. This effort will be extended where necessary for PVOR, DVOR, TVOR, data broadcast VLF, etc., to ensure that new navigation systems are not implemented that require additional user expense without providing some comparable user benefits.

2.7.1.2 047-309-023 Navigation System Data Collection and Error Validation

The reduction of route widths, the increase complexity and variety of navigation systems and operational procedures, and the increase in ATC automation place an increased requirement on the Agency to ensure that navigation systems satisfy their performance requirements. Many of the elements of this program plan have included planning, analyses and simulation. The role of these functions is essential but limited. It will be necessary to provide certain equipments, flight tests and support for this program to collect data and verify navigation system performance, and overall system performance, error models and proposed concepts.

The objective of this program element is to provide the necessary flight test equipment and support to:

1) collect data on system errors such as VOR and DME

2) verify the route sum square (RSS) or proposed alternative method of combining sources.

3) determine data on a limited basis for frequency of intervention or other measures of navigation system errors.

4) calibrate prototype navigation systems and measure accuracy.

Much of this data could be collected by an aircraft equipped with an accurate navigation guidance system. An inertial system with multiple VOR/DME or DME/DME or landing aid updates would serve this purpose.

ATTACHMENT I

PROGRAM FUNDING REQUIREMENTS

ATTACHMENT I

04 NAVIGATION PROGRAM FUNDING

PROGRAM ELEMENT	73	74	75	76	77	78	79	80	81	82
041 VOR Systems	620	1150	1000	700	700	600	500	500	500	500
042 TACAN/DME Systems	185	975	1000	700	500	500	500	500	500	500
043 VLF/Oceanic Systems	305 (190)	730	700	800	800	800	900	900	900	900
044 RNAV Systems	810 (990)	920 (580)	800	550	500	500	500	500	300	100
045 QSAT System	100	240	-	-	-	-	-	-	-	-
046 Freq. Spectrum Plan.	45	100	50	50	50	50	50	50	50	50
047 Nav. Sys. Engr.	(200)	(500)	500	200	200	200	200	200	200	200
TOTAL	2065 (1380)	4115 (1080)	4050	3000	2750	2650	2650	2650	2450	2250

ATTACHMENT I (1)

041 VOR SYSTEMS FUNDING REQUIREMENTS

SUBPROGRAM	73	74	75	76	77	78	79	80	81	82
041-305 VOR Maintenance/ Sustaining Engineering	150K	400K	200K	200K	200K	200K	200K	300K	400K	400K
041-307 VOR Improved/New Systems Development	515K	750K	800K	500K	500K	400K	300K	200K	100K	100K
TOTALS	620K	1150K	1000K	700K	700K	600K	500K	500K	500K	500K

ATTACHMENT I (2)

042 TACAN/DME SYSTEMS FUNDING REQUIREMENT

SUBPROGRAM	73	74	75	76	77	78	79	80	81	82
042-306	137K	347K	200K	200K	200K	200K	200K	300K	300K	400K
042-308	48K	628K	800K	500K	300K	300K	300K	200K	200K	100K
TOTALS	185K	975K	1000K	700K	500K	500K	500K	500K	500K	500K

ATTACHMENT I (3)

043 VLF/OCEANIC FUNDING REQUIREMENT

SUBPROGRAM	73	74	75	76	77	78	79	80	81	82
043-304 VLF Supplement of VOR/DME	325	450	345	440	400	420	480	570	570	560
043-311 Oceanic Navigation Systems	170	280	345	255	250	120	175	100	80	80
043-312 Advanced Air Traffic Management System Support	0	0	10	105	150	260	245	230	250	260
TOTAL	495	730	700	800	800	800	900	900	900	900

ATTACHMENT I (4)

044 RNAV SYSTEM DESIGN

SUBPROGRAM	73	74	75	76	77	78	79	80	81	82
044-326	1670K	1500K	800K	550K	500K	500K	500K	500K	500K	500K
044-327 (Absorbed in 044-326 in FY-74)	130K	-	-	-	-	-	-	-	-	-
TOTAL	1800K	1500K	800K	550K	500K	500K	500K	500K	500	500K

045 QUIET SHORT HAUL AIR TRANSPORTATION SYSTEM (QSATS)

SUBPROGRAM	73	74	75	76	77	78	79	80	81	82
045-390	100K	240K	-	-	-	-	-	-	-	-
TOTAL										

ATTACHMENT I (5)

046 FREQUENCY SPECTRUM PLANNING

SUBPROGRAM	73	74	75	76	77	78	79	80	81	82
046-620	45K	100K	50K	50K	50K	50K	50K	50K	50K	50K
TOTAL	45K	100K	50K	50K	50K	50K	50K	50K	50K	50K

ATTACHMENT I (6)

047 NAVIGATION SYSTEM ENGINEERING

SUBPROGRAM	73	74	75	76	77	78	79	80	81	82
047-309	(200K)	(500K)	500K	200K	200K	200K	200K	200K	200K	200K
TOTAL	(200K)	(500K)	500K	200K	200K	200K	200K	200K	200K	200K